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Forest Pest
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STRATEGIC/TACTICAL PLAN FOR MANAGEMENT OF WESTERN DEFOLIATORS - DRAFT

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Strategic/Tactical Plan for Management of Western Defoliators

DRAFT
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Defoliators

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Introduction

Emphasis on Ecosystem Management and Forest Health has surfaced the need to re-evaluate traditional approaches and strategies for managing defoliators. Management emphasis is changing from attaining predetermined resource targets to restoring and maintaining sustainable forest ecosystems. Increasingly, entomologists and plant pathologists are being asked for information on the roles, functions and interrelationships of insects, including defoliators, and pathogens in, and their effects on, western forest ecosystems ("disturbance ecology"). Such questions and issues are part of our attempts to define forest health, the "range of natural variability", and "desired conditions" for given ecosystems and how they are affected by defoliator activity. The following plan is intended to help focus and connect Forest Pest Management (FPM) with these activities.

This Strategic/Tactical Plan was developed with the following assumptions:

(1) The primary objective of the Plan is to identify and prioritize needs for understanding and managing defoliators of western forest ecosystems. The Plan is intended to provide a framework for: (1) identifying critical issues and information needs relative to understanding the functions and interactions of western defoliators in forest ecosystems; (2) integrating traditional defoliator management strategies and methodologies with current emphases on forest health and ecosystem management; and (3) developing a tactical plan that prioritizes short-term (5 year) defoliator management technology development needs.

(2) The basic objective of western defoliator management is to determine, evaluate and maintain the effects of defoliators on ecosystems/resources at acceptable levels within the context of defined management goals and objectives, the "range of natural variability", and sustainable ecosystems ("desired condition").

(3) The following are needed for effective defoliator management:

- (a) The ability to identify, understand, and predict defoliator effects on diverse resource management goals and objectives, forest health, and sustainable ecosystem structures, processes and functions.
- (b) The ability to predict when and where unacceptable defoliator ecosystem/resource effects are going to occur.
- (c) The availability of strategies, technologies and methodologies to implement effective management of forest ecosystems affected by western defoliators.

The following elements, sub-elements, rationale statements, and action items are intended to focus on these basic issues and help facilitate identification of information and technology development needs.

Element 1. Functions/Interactions of Defoliators in Western Forest Ecosystem Dynamics.

1-A: Identification and Measurement of Effects: There is a need to quantitatively measure defoliator effects (e.g., host mortality, top-kill, loss of foliage, growth-loss) on forest vegetation.

1-A-1: Identify, analyze and summarize existing data to evaluate effects of WSB outbreaks.

Rationale: Analyses of existing data will provide important information on the relationship of defoliation intensity and duration to tree mortality and top-kill. These relationships will be useful in validating and calibrating the current mortality and top-kill equations used in the Budworm Damage Model. The defoliation records will also be useful for validating, calibrating, and streamlining the Budworm Dynamics Model. A Technology Development Project for this purpose was funded in FY94.

Current data from many plots include root disease and dwarf mistletoe information in addition to defoliation data. These data will be useful in the development of a multiple insect and disease model. A project to develop such a model is being planned.

Some existing permanent plots have been treated silviculturally or with insecticides. Data analyses will provide an opportunity to (1) compare effects of WSB between treated and untreated stands, and (2) if appropriate, continue sampling for longer-term comparisons.

Actions:

1) Develop computerized procedures to check Region 6 data sets for errors, correct errors, summarize data, and produce appropriate output tables.

2) Write report on interim results of data collected annually since 1986 from (1) 33 stands in the Blue Mountains of eastern Oregon, and (2) 21 stands established during the early 1990's in the Northern Region.

3) Summarize data from 918 plots previously established in R4.

4) Identify and assess unpublished, unused, information contained in files/records located in various locations (e.g., Forest Pest Management (FPM), Research, and Districts).

5) Standardize permanent plot data in PTIPS.

6) Continue to establish plots, as needed, to validate models.

1-A-2: Continue monitoring/re-measuring permanent plots for effects of defoliation on mortality, top-kill, and growth.

Rationale: Radial and height growth information has not been collected from trees on most existing plots. There is a need to collect growth information from plot trees several years after the collapse of the outbreak. In addition, there is a need to follow top-kill and mortality after collapse of the outbreak to determine if mortality caused by other organisms, such as root disease and bark beetles, is greater than would be expected in non-outbreak areas.

If these plots can be followed for several decades, the long-term effects on stand growth, composition, and structure can be measured and compared to those estimates generated by models for use in environmental and economic analyses. There are very few empirical data sets available on these long-term effects. This information should also be useful in estimating the effects on resources such as vertebrate wildlife, fisheries, recreation, visual resources, and fuels.

Actions:

1) Develop sampling plan for collection of statistically reliable radial and height growth data from permanent plots in the 33 WSB stands in the Blue Mountains of eastern Oregon.

2) Collect radial and height growth data in 1995 and/or 1996 from the 33 WSB stands in the Blue Mountains of eastern Oregon.

3) Continue collecting data from established WSB/Douglas-fir tussock moth (DFTM) plots in Regions 1, 3, 4, and 6.

4) Re-measure the 105 WSB plots in Region 2 established in 1977 and 1978.

5) Prepare report, evaluate conclusions,and develop recommendations from Actions 2-4.

1-A-3: Evaluate the effects of western budworm larval feeding and defoliation on Douglas-fir cone crops.

Rationale: Budworm feeding on cones of host trees can result in significant losses. Even at moderate population levels, a significant portion of cone crops can be destroyed; at high levels, 100% of the cone crop can be destroyed. In addition to direct damage to seeds and cones, loss of foliage can negatively impact cone production. Both the effects of defoliation on cone/seed production and direct effects of budworm feeding should be evaluated and quantified.

Actions:

1) Summarize and analyze published and non-published data/information and make recommendations.

1-A-4: Collect and evaluate data on the effects of the first recorded outbreak of spruce budworms complex in Alaskan white spruce stands.

Rationale: High population levels of Choristineura fumiferana and C. orae were first observed in the Bonanza Creek Experimental Forest near Fairbanks, AK, in July, 1989. Subsequently, population levels, defoliation, and top-kill have generally increased, with approximately 190,000 acres defoliated by C. fumiferana in 1993. The infested stands contain the most productive white spruce stands in Alaska and also include one of the National Long Term Ecosystem Productivity Sites (Bonanza Creek Experimental Forest). Impact plots were established in 1990 and have been measured annually. Information collected from these plots includes; budworm infestation levels, effects on tree growth and mortality, cone and seed productivity, foliage nutrient content, and incidence of bark beetle attack on defoliated trees.

Actions:

1) Analyze data collected from 1990-1993 from the impact plots, develop conclusions and make recommendations.

1-A-5: Identify potentially important western hardwood defoliators and evaluate their roles and effects in western hardwood and riparian ecosystems.

Rationale: Although about 90% of the hardwood volume in the United States occurs in the East, hardwoods are increasingly being recognized as a critical component of western forest and riparian ecosystems. For example, aspen accounts for about 31% of the commercial forest land in Utah and 25% in Colorado. In addition to being a major constituent of the vegetation in riparian areas and woodlands (eg., southwestern Oregon and northern California), hardwoods are also an important component of forest cover types like the Interior Alaska White Spruce-Hardwoods Type and various "mixed conifer" types throughout the west. Important hardwood species include oak, alder, willow, aspen, cottonwood, birch, madrone and maple. In addition to being utilized for wood products, hardwoods are recognized as important to wildlife, forage production, riparian habitats, recreation, aesthetics and represent a key component of biodiversity. These perceived roles are receiving increased importance under the changing emphasis to forest health and ecosystem management.

With the exception of a few defoliators like the forest tent caterpillar, the large aspen tortrix, the fruittree leafroller, and the potential for establishment of gypsy moth, defoliators have generally not been considered major problems for western hardwoods. However, with the emphasis on forest health and ecosystem management, it is prudent to begin to consider the roles and effects defoliators play in western hardwood forest dynamics.

Actions:

1) Participate on teams working with hardwoods to determine and evaluate the roles and effects of defoliators in western hardwood ecosystems.

2) Develop recommendations from team findings.

1-B: Assessment of Effects (Resource Impact Analysis). There is a need to assess the impact, meaning, or significance of the defoliator effects (as defined in 1-A, above) on resource management goals and objectives, ecosystem structure and function, ecosystem sustainability, and the health (desired condition) of the ecosystem. This includes determining how ecological conditions and management activities affect defoliator population dynamics and the consequent effects of defoliators on ecosystems.

1-B-1: Determine the effects of WSB and DFTM on resources and ecosystem structure and function.

Rationale: Considerable information has been compiled concerning the effects of WSB and DFTM defoliation on vegetation and more specifically on the timber resource. However, serious data gaps exist concerning the impacts of WSB and DFTM defoliation on other resources/ecosystem elements (e.g., soils, hydrology, wildlife habitat, fuels).

Actions:

1) Develop a Technology Development Proposal to assess the effects of the 1989-1992 DFTM outbreak in central Idaho and the 1992 WSB outbreak in R1 on specific ecosystem attributes, including big game habitat (thermal cover) and fish habitat (stream temperature). Cooperative TDP project involving FPM (R4, R5, R1) and NFS (R4, R1).

1-B-2: Determine the history of defoliator outbreaks to help define the "range of natural variability".

Rationale: Little is known about the long-term dynamics of the forest-budworm system, especially with regard to the possible influence of climatic variation or human activities such as fire suppression and timber harvesting. However, we do know that forest conditions today are very different than they were 150 years ago. Selective harvesting of pines in the past, the large fires of the late 1800's and fire suppression after 1900 led to higher proportions and densities of budworm host trees than existed in pre-settlement forests. Modern forests provide a favorable food base for budworm which promotes extensive outbreaks. The effects of defoliators on resources may have also changed in response to changing forest conditions.

Actions:

1) Determine the history of WSB/DFTM outbreaks in specific locations throughout the West. The analysis would address how changes in vegetation have affected insect populations and how this translates into effects on forest ecosystems by comparing historic vegetation with current conditions. Changes in defoliator population parameters such as outbreak occurrence, intensity, and duration would also be examined by using historic data and tree-ring analyses.

1-C: Prediction of Effects: There is a need to predict ecosystem effects of defoliators with and without management/treatment.

1-C-1: Validate and calibrate the Budworm Damage Model.

Rationale: Millions of dollars have been spent over the last decade for insecticide treatment of WSB. Estimates of tree effects (mortality, top-kill, radial growth) are based upon estimates generated from processing stand data through the Forest Vegetation Simulator (formerly called the Stand Prognosis Model) linked with the Budworm Damage Model. There is concern that these effects are not adequately portrayed for some stands. This can result in under or over estimating the effects on resources such as wood fiber, vertebrate wildlife habitat, fish habitat, old growth habitat, recreation, visual quality and fuels. There is a need to validate and calibrate (if necessary) the Budworm Damage Model to increase the confidence in the model outputs upon which these high-priced decisions are based.

Actions:

1) After tree data (defoliation, top-kill, growth, and mortality) are summarized from plots in the West, the data should be used to validate/calibrate the Budworm Damage Model.

2) Establish additional permanent WSB plots to gather more information on the influences of silvicultural activities on WSB effects and use such information to validate/calibrate the Budworm Damage Model. Establishment of plots is planned for the following situations: various silvicultural strategies in pure Douglas-fir and in mixed conifer stands (Region 1); uneven-aged vs. even-aged management in mixed conifer and spruce/fir types (Region 2); and several silvicultural strategies vs. no silvicultural action (Region 3).

1-C-2: Evaluate the capabilities and limitations of the WSB/DFTM population dynamics models.

Rationale: The Budworm Population Dynamics Model was developed through funding of the Canada/United States Spruce Budworms Program (CANUSA-West) in the 1980's. This population dynamics model was intended to be a research tool. The CANUSA program planned to evaluate the research model, identify key features that influenced model behavior, and then produce a management-oriented model for forest managers which would provide information regarding the effects of WSB on their forests and, thus, would provide important information for consideration in decision-making processes.

The research model has not been thoroughly evaluated, and the management-oriented version has not been produced. At present the only model that is used is the Budworm Damage Model. A major weakness of using this model is that all outbreak and defoliation parameters (timing and length of outbreak; intensity of defoliation by year of outbreak, tree species, crown third, and foliage age) must be defined by the user, and most times the same scenario is used to predict WSB effects on all stand types within an analysis area. There is a pressing need to have a streamlined, useable population dynamics model which incorporates stochastic processes for timing outbreaks, and which will vary defoliation levels in response to stand characteristics. Until a model with these capabilities is available, there is no useful tool to incorporate WSB effects into forest planning processes. In addition, a model such as this would greatly enhance the reliability of predicted effects used in analyses that affect the allocation of money for large suppression projects using insecticides.

In the 1970's development of a DFTM Outbreak Model was sponsored by the Expanded Douglas-fir Tussock Moth Research and Development Program. This model was linked to the Stand Prognosis Model (now modified and called the Forest Vegetation Simulator or "FVS"). The DFTM Outbreak Model predicts population dynamics on midcrown branches of medium-sized trees. Unfortunately, the link between midcrown branch defoliation and whole tree defoliation is inherently weak, and the model will require major changes to address this problem. To date, the model has not been changed. The model was used for an environmental analysis in 1990 to predict effects on tree growth within a DFTM outbreak area in northeastern Oregon. The analysis resulted in a recommendation of insecticide treatment in 1991. There is concern that the effects on the trees and stands were significantly overstated. Before this can become a reliable tool in which we can be confident, an evaluation of the capabilities and limitations is required, and an effort to incorporate new information is needed.

<u>Actions</u>:

1) A Technology Development Project has been funded to "streamline" the existing WSB Population Dynamics Model which links to the FVS. An intensive analysis of the behavior and sensitivity of the existing population dynamics model will be conducted. Key factors will be extracted from the existing model to create a new streamlined version.

2) A recent evaluation of the mortality and top-kill predictive capabilities of the DFTM outbreak model indicates the need for development of a DFTM damage model which can more accurately incorporate the effects of DFTM on FVS predictions.

1-C-3: Develop procedures for using the WSB/DFTM models in the forest planning process that is changing to reflect ecosystem management needs .

Rationale: Currently, the effects of WSB and DFTM on forest ecosystems are taken into account in a cursory way in forest planning efforts. There is a need to develop procedures for using the models to generate outbreaks in these long-term planning processes to insure that effects on forest ecosystem structure and function are accounted for. This will help reduce the risk of making decisions now that will result in unattainable objectives in the future. With the current efforts to incorporate ecosystem management concepts in forest planning efforts, it is imperative that we be able to model the effects of disturbance agents such as defoliators.

Actions:

1) A Technology Development Project has been funded in FY94 to "streamline" the existing WSB Population Dynamics Model. This should make it useful as a management tool and allow it to be incorporated into the current (and changing) forest planning process.

2) Conduct an evaluation of the use of the "streamlined" version of the WSB Population Dynamics Model with the current forest planning model(s).

1-D: Hazard/Risk Rating: There is a need to develop and evaluate hazard/risk rating systems for use in predictive ecosystem effects modeling and focusing detection and prevention efforts.

1-D-1: Compare, evaluate, and improve existing, and/or develop new, risk and hazard rating systems for WSB/DFTM over different geographical areas.

Rationale: Efficient management of forest insects is best accomplished by setting priorities to work in those areas where the effort will have the greatest effect. Risk and hazard rating systems that evaluate stand and insect population conditions can be used to help set these priorities.

While there are existing systems for both the WSB and the DFTM, there have been times and locations where they have not provided reliable results. Also, forest insect/host interactions tend to differ by geographic region, thus the risk and hazard rating systems need to be calibrated for each region to make them more dependable. Continuing efforts are needed to improve these, and/or develop new, systems.

Actions:

1) Develop/evaluate WSB hazard rating system for the southern Rockies (R3).

2) Validate and modify as needed the Wulf hazard rating system for WSB for Region 1.

3) Develop/evaluate DFTM hazard rating systems for dry Douglas-fir sites in southern Idaho.

Element 2. Population Evaluation

2-A: Survey/Detection: There is a need to develop and use effective survey and detection systems to predict when and where populations will reach levels that might cause unacceptable ecosystem effects.

2-A-1: Evaluate the DFTM early warning pheromone system to improve predictability and efficiency of the system.

Rationale: Since the operational use of the DFTM early warning system was initiated in 1980, there have been three outbreaks of DFTM in the western United States (eastern Oregon, Idaho, and northern California). In at least two of the outbreaks, the early warning system was not considered effective in predicting when and where the outbreaks occurred.

Actions:

1) PNW and R5-FPM initiated a cooperative effort in 1992 to a) assess reasons why the system did not adequately and consistently predict the recent outbreaks and b) evaluate alternative trapping deployment strategies to improve predictability. PNW (Sower) and R5-FPM (Wenz) should report the results of this effort and propose modifications to the system, as appropriate, in 1994-95.

2) Develop/implement changes to system as identified in Action #1.

2-A-2: Examine capabilities for long range forecasting of DFTM populations using historical pheromone trapping data (MAG data base and other sources).

Rationale: Analysis of historical data sets often reveal patterns or relationships associated with cyclic populations. An opportunity exists to evaluate one such data set, the west-wide DFTM pheromone data set residing at MAG. This information has been used locally with limited success to predict population trends. A thorough evaluation of the west-wide data set may reveal patterns which could greatly improve forecasting capabilities.

Actions: No actions proposed at this time.

2-B: Population Dynamics. There is a need for an adequate understanding of defoliator population dynamics, including the relationship between population levels and resource/ecosystem effects.

2-B-1: Evaluate the role of natural enemies in the population dynamics of WSB/DFTM.

Rationale: Many factors, including insects and diseases, are known to play an important role in maintaining defoliator populations at low densities. Generalized predators such as birds and ants play an important role in the population dynamics of the WSB. As we move toward ecosystem management, the need to explore natural processes and controls will be highlighted. An alternative to treating "high" or outbreak populations of defoliators, is to try and keep defoliator populations at low levels for longer periods of time. We need to further explore the relationship of selected natural enemy arthropod populations and defoliators during both low level and epidemic population levels. Multi-year data are needed on how these populations interact over time.

Actions:

1) Establish plot systems to examine the relationship between arthropod natural enemies and defoliators over time. Several management scenarios, which include the effects of fire, should be represented by the plot network.

2) Standardize variables and coordinate data collection across regions.

3) Develop and/or refine monitoring/sampling techniques for assessing natural enemy populations across regions.

2-B-2: Continue to evaluate the potential of using WSB pheromone trap catches to predict subsequent defoliation.

Rationale: In WSB analyses, a prediction of the following year's population/defoliation levels is helpful in providing lead time for making management decisions. In the past, such predictions were made using results from late summer/early fall egg mass sampling. This was expensive and predictions were not very reliable. Currently, pheromone trapping is generally used to predict next year's population/defoliation levels. The predictive capabilities of pheromone trapping, with the trapping methods currently employed, are not much better than those of egg mass sampling: but the sampling process is cheaper and can be done with fewer people. There is a need to improve the ability to predict future WSB population/ defoliation levels through refinement of pheromone data trapping methods and analyses. This will help improve decision-making.

Actions:

1) Conduct analyses of pheromone trap data collected by PNW over the last several years. Such analyses would use GIS to incorporate variables (e.g., defoliation history and intensity, host type, soils, weather) into predictive equations to more accurately predict defoliation levels the year following flight.

2) Explore feasibility of commercial production of the WSB pheromone.

3) Explore opportunities to combine/add pheromone trapping plots with other WSB population and/or foliage quality plots.

2-C: Population Assessment and Monitoring: There is a need to develop methodologies for spatial and temporal assessment/monitoring of defoliator populations, and for summarizing and analyzing the data obtained through use of these methodologies.

2-C-1: Evaluate the need to continue the monitoring of existing WSB/DFTM population plots established by PNW (Wickman, Mason).

Rationale: Plots exist in Oregon and Washington from which about 15 years of population density information for both WSB and DFTM have been collected. Data from such long-term plots should prove to be extremely valuable with the move toward using concepts which will allow sustainable forest ecosystems. There are few opportunities currently to gather sets of long-term data and, in fact, research organizations appear to be providing little support for future projects which involve collecting insect population data over multiple years. This opportunity to continue adding information to the 15-year sets of data should not be missed.

Actions:

1) Examine plot site information, tree data, and WSB/DFTM population information and evaluate to determine worth/need for continued sampling.

2) If continuation of data collection is warranted, investigate ways to obtain resources/funding to continue.

2-C-2: Develop a sampling system for western hemlock looper.

Rationale: For the last two or three years, areas with defoliation caused by western hemlock looper (WHL) have been detected in British Columbia and Washington. This defoliation is occurring primarily in interior forests, whereas most of the early research data were collected in coastal forests. Adequate sampling systems are not available for estimating insect population densities that can be related to effects on trees.

A cooperative study by the Canadian Forest Service and Simon Fraser University to develop a pheromone trapping and forecasting system was initiated in 1992 and continued in 1993. Estimates of larval, pupal, and overwintering egg population densities, and defoliation severity, were made at 27 sites. Preliminary results show promise for predicting succeeding generation population levels. However, there is no information that relates WHL population levels to effects on trees and stands.

There is a need to develop population sampling systems that relate population densities to effects on trees and stands. This would help improve decision-making and provide an opportunity to adapt one of the defoliator models to simulate the effects of WHL on trees and stands.

Actions:

1) No action needed at this time. Projections are that populations will decline in 1994 in Washington and WHL is not currently a high priority with forest managers.

Element 3. Management and Assessment of Treatment Effects.

3-A: Habitat Management: There is a need to develop and assess silvicultural techniques and approaches designed to prevent and/or reduce unacceptable defoliator effects. Defoliator effects should be considered in the development and implementation of silvicultural prescriptions.

3-A-1: Evaluate the efficacy of silvicultural treatments designed to prevent/reduce unacceptable effects of defoliation on vegetation, resources, and ecosystems.

Rationale: Silvicultural treatments are frequently recommended as ways to prevent unacceptable losses. Unfortunately there is not much documented evidence that supports the premise that these treatments can prevent or even reduce future losses. Many of the recommended treatments are counter to the prescriptions being recommended under adaptive forestry for extracting resources and for maintaining ecosystem health. Therefore an evaluation of the efficacy of silvicultural treatments is needed if we propose to continue to recommend these treatments for prevention or reduction of impacts caused by WSB and DFTM.

Actions:

1) Establish additional permanent WSB population/effects plots in areas where sustainable ecosystem concepts are being incorporated using non-traditional silvicultural techniques (See section 1-C-1, Action 2).

2) Continue to monitor plots established across various silvicultural treatments in R1 and R4.

3-B: Population Management: There is a need to develop and assess strategies, techniques, and methodologies, including semiochemicals, microbials, growth regulators, biological controls and chemical insecticides, maintain defoliator populations at, or reduce to, acceptable levels relative to resource/ecosystem effects.

3-B-1: Determine the potency of TM BioControl-1 with Entotech carrier on wild populations of the DFTM from different geographical areas using a) lab bioassays and b) field tests.

Rationale: TM BioControl-1 is a registered biological pesticide containing polyhedral inclusion bodies of a naturally occurring Douglas-fir tussock moth nucleopolyhedrosis virus as its active ingredient. This virus is very selective to species of tussock moth. Aerial and ground applications of TM BioControl-1 have suppressed DFTM populations. However, the most recent use of TM BioControl-1 was not successful. The recommended application rate had been established from tests on long-standing laboratory colonies that had apparently been weakened through inbreeding. In the field, this dosage rate was not adequate. To avoid future failures, the dosage rate needs to be established by testing on colonies from wild populations, including those from different geographical areas so as to account for any genetic resistance that may exist.

In addition, a virus carrier, developed by Entotech, has been shown to be an effective carrier for Gypcheck, a viral insecticide used in gypsy moth management. Studies have shown that this carrier is easier to use (handle, mix, and store) than carriers currently being used with TM BioControl-1.

Actions:

1) Conduct lab bioassays and field tests of TM BioControl-1 plus Entotech's carrier to determine rain fastness, persistence, viability, and efficacy.

3-B-2: Pursue and obtain registration of the DFTM pheromone for mating disruption.

Rationale: Aerial application of the DFTM pheromone can effectively reduce mating success and can be considered for use alone or in conjunction with other prevention/suppression methodologies.

Actions:

1) PNW and FPM (WO and appropriate Regional personnel) continue to pursue registration in 1994.

3-B-3: Improve DFTM pheromone application and delivery technology and formulation for mating disruption.

Rationale: It is important to control the DFTM moth at low population levels to avoid defoliation and damage to the trees that results when high numbers of larvae are present. Mating disruption accomplished by the application of synthesized sex attractant pheromones has been found to fulfill this need. The procedures and equipment for formulation, application, and delivery need to be evaluated, improved, and standardized so as to be available for operational use during the next outbreak.

Actions:

1) The Missoula Technology Development Center should complete and report on the survey of pheromone application equipment and technology and develop recommendations.

2) Devise plans to obtain or develop equipment/technologies.

3-B-4: Conduct field tests of DFTM pheromone for mating disruption to determine optimal time of treatment within an outbreak cycle.

Rationale: It is important to control the DFTM at low population levels in order to avoid the defoliation and damage to the trees that result when high numbers of larvae are present. Work is needed to determine the optimal timing for disrupting DFTM mating during its outbreak cycles.

Actions:

1) Develop plans to utilize outbreak opportunities to assess timing of DFTM mating disruption strategy

3-B-5: Evaluate the potential for using natural enemies for population management of DFTM/WSB.

Rationale: Thirty-two species of insectivorous birds are known to feed on DFTM and WSB and 20 of these are neotropical migrants. In addition, there are at least 120 species of parasites of WSB and DFTM. Many species of ants, birds and spiders are very effective predators of defoliators. Ants are dominant in the ecological hierarchy because of the position they occupy and their abundance in almost every ecosystem. There has been considerable interest and work over the last few decades in trying to manipulate predaceous ants to benefit forest health. Research efforts have been aimed at protecting, encouraging, and transplanting ants.

Western forests that are known to be susceptible to WSB and DFTM where timber yields are not the main or only consideration, provide an excellent opportunity to evaluate and utilize the management potential of natural enemies. Predatory ants and many insectivorous birds are influenced by the availability of standing or down dead wood, or stumps. Stand structure also strongly influences the presence and abundance of many predaceous ant and bird species.

Actions:

1) Examine the habitat requirements, such as stand conditions, for previously identified key natural enemies of WSB and DFTM.

2) Develop effective monitoring methods for key natural enemies of WSB and DFTM.

3) Evaluate the effects of harvesting practices and prescribed fires on natural enemy populations.

4) Determine potential standards for log retentions to protect and enhance natural enemy populations.

3-B-6: Evaluate the impacts of microbial insecticides on non-target Lepidoptera and other organisms.

Rationale: Microbial insecticide treatments have proven to be effective, economical, and in general, socially acceptable for use against many forest defoliators. However, the direct, indirect and cumulative effects of these microbials on non-target organisms in the West are largely unknown. This lack of information has resulted in a number of questions and concerns from resource managers, resource specialists, and interested publics that should be addressed so that proposed treatments can be adequately evaluated. Studies are needed to determine baseline population information, develop effective and efficient sampling procedures, and to monitor post treatment effects under a wide range of conditions in the West.

Actions:

1) Initiate baseline surveys for organisms, especially Lepidoptera, potentially subject to impacts by use of microbial insecticide treatments.

2) Complete R3 report on baseline survey for Lepidoptera.

3) Identify and develop annotated list of taxonomists available to identify non-target organisms to species level.

4) Identify alternative users of taxonomic expertise in the non-target area and sources of cooperative funding for taxonomic support.

5) Develop/evaluate field methods to predict/monitor microbial insecticide effects on non-targets.

3-B-7: Evaluate the effects of population suppression methodologies on threatened, endangered, and sensitive species.

Rationale: Western defoliator population suppression methodologies have the potential to affect threatened, endangered, and sensitive (TES) species. The potential effects of population suppression, both direct and indirect, continue to pose unanswered questions and concerns among forest managers, resource specialists, and interested publics. However, very little information is available regarding these potential effects in the West. While a few studies have been initiated to determine some of these effects, additional studies are needed and should be supported to determine if and how various treatments do affect TES species. Specific needs include baseline information on potentially affected TES species, development of population sampling methodologies and analysis techniques, and post treatment population monitoring of TES species to determine effects of various treatments westwide.

Actions: No actions proposed at this time.

3-B-8: Develop and evaluate methods/systems capable of treating individual trees with various insecticides that are safe, efficient, economical, and environmentally acceptable.

Rationale: Current methods of treating single trees with pesticides is hazardous, inefficient, costly and often unacceptable to segments of the public. Practices include hydraulic spraying with high volumes of diluted pesticides, high pressure airblast spraying that causes excessive off-target movement, and backpack spraying from elevated platforms. There is a need for single tree protection to protect white pine blister rust candidate and proven resistant trees, selected trees in seed orchards, seeds/cones on selected trees, trees of historic and aesthetic value, urban street and landscape trees, trees in developed campgrounds and administrative sites, and trees bordering urban/wildlife interfaces.

Actions:

1) Continue research and development of a system, currently in progress at the Pacific Southwest Station, that involves installation of a semi-permanent hose and nozzle system in selected trees.

2) Request the Missoula Technology and Development Center to establish an FPM project to address "Single Tree Application Systems".

Element 4. Technology Transfer.

4-A: Information Transfer: There is a need for timely transfer of information to, and coordination with, cooperators (NFS, Research, States, community interest groups).

4-A-1: Develop procedures to assist in the decision-making, planning, and implementation and reporting of suppression projects.

Rationale: The documentation of standardized procedures for preparing and conducting suppression projects would be very useful. Reports of previous projects are often not available or do not include enough detail to be a useful guide in the preparation of environmental statements, work plans, or field procedures. A procedures manual would greatly facilitate this process, while helping to assure that important details are not overlooked.

Actions:

1) Review draft manual being prepared by R8/R9 and make recommendations.

2) Implement recommendations as appropriate.

Appendix

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